ORNL-CTP-95-03 and ASHEP-95-01

Effect of $q\bar{q}$ Initial-state Interaction on Dilepton Emission Rate from Quark-Gluon Plasma

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(February 7, 2008)

Abstract

We calculate the dilepton production rate from a thermalized quark-gluon plasma in heavy-ion collisions at RHIC energies. Higher-order QCD corrections are included by using an analytical correction factor $K^{(i)}$, which takes into account the $q\bar{q}$ initial-state interactions. We show that the analytic correction factor gives very good agreement with experimental Drell-Yan data and leads to large enhancement of the thermal dilepton emission rates. We compare the thermal dilepton yields with the expected production from open-charm decays and Drell-Yan background and assess the prospects of observing thermal dileptons from the quark-gluon-plasma at invariant masses of a few GeV.

PACS number(s): 25.75.+r, 24.85.+p, 12.38.Mh, 13.90.+i

High-energy heavy-ion collisions have become the focus of intense experimental and theoretical research in recent years because of the possibility of producing hadron matter in a deconfined quark-gluon plasma (QGP) state during such collisions [1]. Various signals have been proposed as a probe of this new phase of nuclear matter. In particular, electromagnetic signals comprising dileptons and photons, are recognized as direct probes for the QGP phase [2–4], since they weakly interact with the hadronic medium in which they are produced. The magnitudes of the dilepton yields depend on the cross sections for the basic process producing the dileptons.

The dilepton signals indicative of the QGP phase are those produced by the annihilation of $q\bar{q}$ pairs through virtual photon intermediate states. To be meaningful signals, they must be clearly delineated from other sources of dilepton pairs like Drell-Yan process, open charm decays, vector meson decays, and so on. The problems associated with these backgrounds have been discussed in the literature [5–7,4,8,9] and their contributions are known to vary with the invariant masses of the dileptons and the kinematic regions under consideration [2,10–13]. For dilepton pairs in the invariant mass region of 2 to 7 Gev, the charm dileptons and DY dileptons are expected to be the major background to detection of thermal dileptons from the quark-gluon-plasma phase. We shall discuss our thermal dilepton predictions in the light of these backgrounds.

Thermal dileptons as well as Drell Yan pairs originate from the electromagnetic annihilation of quark-antiquark pairs through intermediate virtual photons. While the surroundings that host the processes for dilepton production from the thermal plasma or the DY production during nuclear collisions are vastly different, the basic process corresponding to the channel $q\bar{q} \to \gamma^* \to l^+l^-$ is the same for the two cases. For comparative analyses, therefore, the dileptons should be corrected similarly for the effects that modify the tree-level diagrams, whether the dilepton source is the thermal plasma or the DY mechanism. For the latter processes, it has been already generally recognized in perturbative QCD that the lowest-order Feynman diagrams give only an approximate description [14–18]. In order to bring the lowest-order QCD predictions into agreement with experiment, the lowest-order

DY results must be multiplied by a phenomenological K-factor, which has a magnitude of the order of 3. The K-factor can be accounted for in terms of higher-order QCD corrections, the most important effects being the vertex correction arising from the initial-state interactions of the $q\bar{q}$, prior to their annihilation into the virtual photon producing the dileptons [14,15]. These higher-order QCD corrections are operative also for $q\bar{q}$ annihilation in the QGP, and the dilepton production cross section in the QGP must be similarly corrected.

In this work we investigate dilepton production from the QGP in nucleus-nucleus collisions at RHIC energies, by incorporating these QCD corrections through an analytic correction factor presented recently [19]. We compare our calculated rates with those expected from open charm production and the DY process in the energy range of a few GeV. Our calculated values of open charm dileptons exceed those of the DY process, in conformity with recent findings [12]. However, we show that the thermal dilepton yield, computed with the QCD corrections can be comparable and in some scenarios can be well above the background, so that prospects for its observation at RHIC energies becomes promising.

We use the analytical correction factor for the basic reaction processes involving q and $\bar{q}$ [19], for the whole range of relative energies. For low energies, the correction factor is obtained by studying the distortion of the wave function by virtue of the q-$\bar{q}$ color potential arising from virtual gluon exchange. At high energies, the correction factor is chosen to match well-known PQCD results which give good agreement with the experimental correction factor for the initial- or final-state interactions as applicable. An interpolation to join the correction factor from low energies to these well-known perturbative QCD correction factors at high energies is made by following the procedure suggested by Schwinger [20].

The analytical correction K-factor for the annihilation or the production of a $q\bar{q}$ pair with an invariant mass $M^2 = s$ is explicitly given by [19]

$$K^{(i,f)}(q) = \frac{2\pi f^{(i,f)}(v)}{1 - \exp\{-2\pi f^{(i,f)}(v)\}}(1 + \alpha_{\rm eff}^2)\,, \tag{1}$$

where the flavor label q in $K^{(i)}(q)$ is included to indicate that $K^{(i)}$ depends on the quark mass m_q, the superscripts (i) and (f) denote $q\bar{q}$ initial-state annihilation and $q\bar{q}$ final-state

production respectively.

$$f^{(i)}(v) = \alpha_{\rm eff}\left[\frac{1}{v} + v\Big(-1 + \frac{1}{2\pi^2} + \frac{5}{6}\Big)\right], \tag{2}$$

$$f^{(f)}(v) = \alpha_{\rm eff}\left[\frac{1}{v} + v\Big(-1 + \frac{3}{4\pi^2}\Big)\right]. \tag{3}$$

In the above equations, v is the relative asymptotic velocity for the quark and the antiquark in their center-of-mass system

$$v = \frac{(s^2 - 4sm_q^2)^{1/2}}{s - 2m_q^2}, \tag{4}$$

and $\alpha_{\rm eff}$ is the effective strong interaction coupling constant related to the strong interaction coupling constant $\alpha_{\rm s}$ by the color factor C_f

$$\alpha_{\rm eff} = C_f \alpha_{\rm s}\,. \tag{5}$$

For dilepton production, the q and $\bar{q}$ must be in the color singlet state, i.e. $C_f = -\frac{4}{3}$, and the running coupling constant is taken as [16,17]

$$\alpha_{\rm s} = \frac{12\pi}{(33 - 2n_f)\ln(M^2/\Lambda^2)}\,. \tag{6}$$

To demonstrate the validity of the correction factor, we apply it first to the Drell-Yan case and compare with known experimental data.

The lowest-order Drell-Yan distribution for nucleon-nucleon collisions is given by

$$\frac{d^2\sigma_{DY}^{NN}}{dMdy} = \frac{8\pi\alpha^2}{3sN_cM}\sum_{q=u,d,s}\Big(\frac{e_q}{e}\Big)^2[q_q^a(xe^y)\bar{q}_q^b(xe^{-y}) + \bar{q}_q^a(xe^y)q_q^b(xe^{-y})] \tag{7}$$

where $x = M/\sqrt{s}$ and y is the rapidity. $q_q^{a,b}(xe^y)$ and $\bar{q}_q^{a,b}(xe^y)$ refer to the quark and antiquark distributions in the nucleons a and b respectively.

Correcting for initial-state color interaction we obtain

$$\frac{d^2\sigma_{DY}^{NN}}{dMdy} = \frac{8\pi\alpha^2}{3sN_cM}\sum_{q=u,d,s}K^{(i)}(q)\Big(\frac{e_q}{e}\Big)^2[q_q^a(xe^y)\bar{q}_q^b(xe^{-y}) + \bar{q}_q^a(xe^y)q_q^b(xe^{-y})] \tag{8}$$

The DY distributions for equal-nuclei nucleus-nucleus collisions are obtained from the nucleon-nucleon case by using

$$\frac{d^2N_{DY}^{AA}}{dMdy} = \frac{3}{4\pi(r_0')^2}\ A^{4/3}\ \frac{d^2\sigma_{DY}^{NN}}{dMdy}\,, \tag{9}$$

where A is the atomic number of the colliding nuclei and $r_0^{'} = 1.2$ fm.

Figure 1 shows the FNAL-605 experimental data [21] for the differential cross section $sd^2\sigma/d\sqrt{\tau}dy$ as a function of $\sqrt{\tau} = M/\sqrt{s}$ for different rapidity y intervals, compared to the corrected cross-sections using the Duke and Owens structure functions with $\lambda = 0.2$ GeV [22], obtained by multiplying the lowest-order Drell-Yan calculations by the correction factor $K^{(i)}$. No further multiplicative factors are needed to obtain the very good fit shown in fig. 1, which thus demonstrates the reliability of the correction factor $K^{(i)}$. It is interesting to note that the function $K^{(i)}$ from Eq. (8) which gives a good fit in Fig. 1 is not a constant of the invariant mass M. It is equal to 2.5 for $M = 3.9$ GeV and 1.8 for $M = 17$ GeV. There is thus a 30 % variation of $K^{(i)}$ as M varies from 4 to 17 GeV.

For lowest-order calculations, the rate for the production of dileptons with an invariant mass M per unit four-volume in a thermalized quark-gluon plasma (with three flavors) depends on the temperature T of the system and can be written in the form [7,1]

$$\frac{dN_{l^+l^-}}{dM^2d^4x} \approx N_cN_s^2 \sum_{q=u,d,s}\left(\frac{e_q}{e}\right)^2\frac{\sigma_q(M)}{2(2\pi)^4}M^2\sqrt{1-\frac{4m_q^2}{M^2}}\ TMK_1\left(\frac{M}{T}\right), \tag{10}$$

where $\sigma_q(M)$ is the lowest-order $q\bar{q} \to l^+l^-$ cross section at the center-of-mass energy M given by [1]

$$\sigma_q(M) = \frac{4\pi}{3}\frac{\alpha^2}{M^2}\left(1-\frac{4m_q^2}{M^2}\right)^{-\frac{1}{2}}\sqrt{1-\frac{4m_l^2}{M^2}}\left(1+2\frac{m_q^2+m_l^2}{M^2}+4\frac{m_q^2m_l^2}{M^4}\right), \tag{11}$$

m_l and m_q are the rest masses of the lepton l and the quark q respectively, and K_1 is the modified Bessel function of first order.

The integration of Eq. (10) over the transverse dimensions and the proper time interval τ_0 (the formation time) to τ_c (the hadronization time) gives the invariant mass-squared distribution of dileptons produced from the system while it was in the quark-gluon plasma phase as [7,1]

$$\frac{dN_{l^+l^-}}{dM^2dy} \approx \mathcal{A}N_cN_s^2 \sum_{q=u,d,s}\left(\frac{e_q}{e}\right)^2\frac{\sigma_q(M)}{2(2\pi)^4}\left(1-\frac{4m_q^2}{M^2}\right)^{\frac{1}{2}}\ \frac{3\tau_0^2T_0^6}{M^2}\left[H\left(\frac{M}{T_0}\right)-H\left(\frac{M}{T_c}\right)\right], \tag{12}$$

where $\mathcal{A}$ is the transverse area of the collision region, T_0 and T_c are the initial and final temperatures of the ideal QGP phase, and

$$H(z) = z^2(8+z^2)K_0(z) + 4z(4+z^2)K_1(z)\,.$$

To delineate the QGP dileptons from other sources of dileptons, particularly the Drell-Yan background, we need to have good estimates of the dilepton production from the different sources at matching levels of accuracy. It is hence necessary to modify Eq. (12) by incorporating the higher-order QCD corrections. The interpolation from low to high relative velocities extends the usefulness of the correction factors $K^{(i)}$ given by Eq. (1) to account for higher-order QCD effects. The modified rate of dilepton production then becomes

$$\frac{dN_{l^+l^-}}{dM^2dy} \approx \mathcal{A}N_cN_s^2 \sum_{q=u,d,s} K^{(i)}(q)\Big(\frac{e_q}{e}\Big)^2 \frac{\sigma_q(M)}{2(2\pi)^4}\Big(1-\frac{4m_q^2}{M^2}\Big)^{\frac{1}{2}}\,\frac{3\tau_0^2T_0^6}{M^2}\Big[H\Big(\frac{M}{T_0}\Big)-H\Big(\frac{M}{T_c}\Big)\Big]. \quad (13)$$

To calculate Eq. (12) or Eq. (13), we need to know the temperatures T_0 and T_c, and the "formation" or "materialization" time τ_0. We use $T_c = 180$ MeV. The Monte Carlo simulation program "MARCO" [23], which is based on the Glauber multiple-collision model and reproduces the peak value of dN/dy in nucleus-nucleus collisions, is used to calculate the rapidity density of the produced particles (mostly pions). The peak energy density ε is related to the peak rapidity density $dN/dy|_{peak}$ in the Bjorken scaling hydrodynamic model [24,1] as

$$\varepsilon = \frac{m_{_T}}{\tau_0\mathcal{A}}\,\frac{dN}{dy}\Big|_{peak}\,, \quad (14)$$

where $m_{_T} = \sqrt{m_\pi^2 + p_{_T}^2}$, m_π is the pion mass, and $p_{_T}$ is the pion transverse momentum, which varies with the center-of-mass energy of the colliding nuclei as [1]

$$p_{_T} = 0.27 + 0.037\ln(\sqrt{s})\,.$$

The temperature T_0 is then approximated as [24,1]

$$T_0 = \Big[\frac{30}{37}\,\frac{\varepsilon}{\pi^2}\Big]^{1/4}. \quad (15)$$

The value of the formation time τ_0 is found to play an important role in determining the value of the initial temperature T_0 of the QGP. It has been given different values in the literature. In the following, we use the values obtained from MARCO for the peak dN/dy, typically 2144 and 231, in the central collisions of Au + Au and S + S, respectively, at RHIC energies. The common argument assumes that τ_0 should be of the order of a typical strong interaction time scale of 1.0 fm/c, as proposed by Bjorken [24]. Using this value, Eq. (14) and Eq. (15) then give $T_0 = 262$ MeV for Au+Au and $T_0 = 202$ MeV for S+S. Shuryak *et al.* [25,26] assume a different scenario for calculating the thermalization time τ_0. In the "hot glue" scenario, the thermalization time of the quark-gluon plasma is expected to be within the range $0 < \tau_0 < 0.3$ due to gluon rescattering and production mechanisms. This picture gives a temperature much higher than that of the Bjorken scenario. Ruuskanen [4] assumes that the quark-gluon plasma may thermalize at an early time $\tau_0 = 0.5$ fm/c which gives $T_0 = 312$ MeV for Au+Au and $T_0 = 241$ MeV for S+S. Alternatively, Kapusta [3] uses a different approach to estimate τ_0. Assuming that the partons will have a thermal distribution right after they are put on the mass shell, and that the initial rapidity density is the same as the observed one, Kapusta concludes that $\tau_0 T_0 = constant$. Using the uncertainty principle and putting $\Delta E = 3T_0$, he then estimates the *constant* to be 1/3, i.e

$$\tau_0 T_0 = 1/3 \,, \tag{16}$$

which gives $T_0 = 590$ MeV and $\tau_0 = 0.11$ fm/c for the collision Au+Au and $T_0 = 421$ MeV and $\tau_0 = 0.16$ fm/c for the collision S+S.

Due to the importance of the charm dilepton background, it is necessary to estimate the charm contribution for a comparitive study. For charm production, the gluon fusion channels as well as the $q\bar{q}$ annihilation via virtual gluon modes must be included [27].

The basic cross section for $q\bar{q} \to g^* \to c\bar{c}$, averaged over initial and summed over final colors and spins can be written as

$$\sigma_{q\bar{q}}(M_{c\bar{c}}) = \frac{8\pi\alpha_s^2}{27M_{c\bar{c}}^2}\left(1 + \frac{\eta}{2}\right)\sqrt{1-\eta} \tag{17}$$

where $\eta = 4m_c^2/M_{c\bar{c}}^2$., with m_c being the mass of the charm quark and $M_{c\bar{c}}$ being the invariant mass of the produced $c\bar{c}$ pair.

The corresponding expression for the gluon fusion mode, averaged over initial gluon types and polarizations and summed over final colors and spins is [1]

$$\sigma_{gg}(M_{c\bar{c}}) = \frac{\pi\alpha_s^2}{3M_{c\bar{c}}^2}\Big\{(1+\eta+\frac{1}{16}\eta^2)\ln\Big(\frac{1+\sqrt{1-\eta}}{1-\sqrt{1-\eta}}\Big) - \Big(\frac{7}{4}+\frac{31}{16}\eta\Big)\sqrt{1-\eta}\Big)\Big\} \tag{18}$$

The above cross sections must be convoluted over the quark and gluon distributions respectively as for the DY case to obtain the overall charm yield for comparison with the QGP signals. The charm production can then be written for the nucleon-nucleon case as

$$\begin{aligned}\frac{d^2\sigma_{c\bar{c}}^{NN}}{dM_{c\bar{c}}dy_{c\bar{c}}} = K\Big\{\Big(\sum_{q=u,d,s}\sigma_{q\bar{q}}(M_{c\bar{c}})[q_q^a(xe^y)\bar{q}_q^b(xe^{-y}) + \bar{q}_q^a(xe^y)q_q^b(xe^{-y})]\Big) \\ +\Big([g^a(xe^y)g^b(xe^{-y})] + [a \leftrightarrow b]\Big)\sigma_{gg}(M_{c\bar{c}})\Big\}\end{aligned} \tag{19}$$

where $x = M_{c\bar{c}}/\sqrt{s}$, $M_{c\bar{c}}$, $y_{c\bar{c}}$ are the invariant mass and the rapidity of the $c\bar{c}$ pair. The factor K in this case is an empirical factor and is usually taken to be 3 [28].

The $c\bar{c}$ pairs produced by the $q\bar{q}$ or gg reactions hadronize to D mesons which subsequently decay through semi-leptonic channels, such as $D \to l + X$ to leptons. Leptons from a decaying $D\bar{D}$ pair comprise a dilepton and the charm production rates can be mapped into the resulting decay dilepton distributions with invariant mass M_{l+l-} and rapidity y_{l+l-} by a Monte Carlo technique to generate the dileptons from charm decays.

The nuclear-nuclear charm dilepton cross section can be obtained from the nucleon-nucleon one according to

$$\frac{d^2N_{l^+l^-}^{AA}}{dM_{l^+l^-}dy_{l^+l^-}} = \frac{3}{4\pi(r_0')^2}\,A^{4/3}\,\frac{d^2\sigma_{l^+l^-}^{NN}}{dM_{l^+l^-}dy_{l^+l^-}}\,, \tag{20}$$

The dilepton production rates per unit time from a thermalized QGP, which may be formed after the collisions of Au+Au and S+S at an energy $\sqrt{s}$ = 200 GeV, for three different values of the variable τ_0 are shown in Fig. 2 and Fig. 3, respectively. The solid curves in Fig. 2(a) and Fig. 3(a) show those rates given by Eq. (12) using the results of the lowest-order cross section of dileptons production. The solid curves in Fig. 2(b) and

Fig. 3(b) show the same rates taking into account the correction factor $K^{(i)}$ [Eq. (13)]. The dotted-dash curves in both Fig. 2 and Fig. 3 show the Drell-Yan rates. The dotted curve is the dilepton rates from the open-charm mesons decays.

The virtual photon annihilation mode selects the annihilating $q\bar{q}$ pair to be in the color-singlet states and thus the interaction between q and $\bar{q}$, before they annihilate, is attractive. The effect of $q\bar{q}$ initial-state interaction leads to an enhancement factor $K^{(i)}$, as shown in Fig. 2 and Fig. 3. Because the coupling constant increases and the relative velocity decreases as the invariant mass decreases, the correction factor rises considerably with the decrease of invariant mass. The effect of the higher-order QCD corrections is to enhance the tree-level dilepton cross section by a factor of about 5 at $\sqrt{s} = 1$ GeV, and by a factor of about 3 at $\sqrt{s} = 2 - 3$ GeV.

It is seen that for the collision Au+Au, the temperatures $T_0 = 262$ MeV and $T_0 = 312$ MeV lead to the result that the dilepton rates from the Drell-Yan process (the dashed curves in Fig. 2) exceed those from the QGP (the solid curves in Fig. 2(a)) above 1 GeV, and the charm dilepton contribution is even higher. The temperature $T_0 = 590$ Mev allows the uncorrected thermal rate to exceed the DY and charm dileptons up to almost 6 Gev and indicates it may be possibile to detect the signal. However, the inclusion of the correction factor $K^{(i)}$ changes the situation dramatically. It increases the thermal rates (solid curves in Fig. 2(b)) so that they exceed the Drell-Yan background up to an invariant mass of $M = 2$ GeV even for the lower temperature models and is comparable to the charm dileptons, which may prove to be detectable if the contribution of the charm dileptons can be found by independent charm measurement. For the temperature $T_0 = 590$ MeV, it further improves the prospects to detect the QGP dileptons since their rates are now well above the background up to $M = 7.5$ GeV.

Similarly, for the collision S+S at an energy $\sqrt{s} = 200$ GeV, as shown in Fig. 3 at lower temperatures $T_0 = 202$ MeV and $T_0 = 241$ MeV, the dilepton rates from the Drell-Yan and charm background exceed those from the QGP. The inclusion of the correction factor

$K^{(i)}$ enances the QGP dilepton yield so that it exceeds the Drell-Yan dilepton yield up to an invariant mass of $M = 1.5$ GeV, and is comparable to the charm dileptons. For the temperature $T_0 = 421$ MeV, the QGP dilepton rate, without the correction factor $K^{(i)}$, exceeds the Drell-Yan dileptons up to an invariant mass of $M = 4.5$ GeV, and the charm dileptons up to 2 GeV. With the correction factor $K^{(i)}$, the thermal dilepton yield exceeds the DY yield up to 5.5 GeV and the charm dileptons up to 3.5 GeV, so that detection prospects increase considerably.

While different temperatures have been proposed for the initial state of the QGP, the observation of the initial temperature is an experimental question. In this regard, higher-order QCD corrections, as accounted for by using the $K^{(i)}$ factor, enhance the possibility of detecting dileptons from the quark-gluon plasma for both Au+Au and S+S collisions, even if the initial temperature turns out to be lower than about 350 MeV. On the other hand, without the QCD corrections, the thermal dilepton yield from the QGP is lower than that from the Drell-Yan and charm decay processes and will be difficult to detect. It may be noted that recent calculations, approaching the first order corrections in a different manner, using thermal masses and finite temperature QCD effects also indicate an enhanced dilepton yield from the thermal plasma [29].

In the plasma, the color charge of the constituents is subject to Debye screening which is characterized by the Debye screening length λ_D, which depends on the temperature T. The Debye screening length at a temperature of 400 MeV is about $\lambda_D \sim 0.2$ fm. On the other hand, the electromagnetic annihilation into dileptons occurs within an extremely collapsed space zone characterized by the linear q-$\bar{q}$ distance $\sim \alpha/\sqrt{s}$, which is about 0.0029 fm for the annihilation of a light quark-antiquark pair at 0.5 GeV, and is much smaller than the Debye screening length λ_D. The interaction between the quark and the antiquark is not expected to be much affected by Debye screening in the region where annihilation occurs. Therefore, we expect that our correction factor for dilepton production by $q\bar{q}$ annihilation in the plasma will not be modified much by the addition of Debye screening corrections.

In the charm estimates, the open-charm production was based on a model of gluon fusion and $q\bar{q}$ annihilation, with an empirical K factor independent of the color state of the reacting partons. In this region of $c\bar{c}$ production near the threshold, it is expected that the initial- and final-state interactions of the participating gluons, quarks, or antiquarks are important, and the effective interaction depends on the color multiplet of the participating partons [19]. A careful examination of these known effects to study open-charm production will be of interest to augment the investigation here and to reexamine the results of [12].

Although we have specifically focussed on the experimental situation expected at RHIC, the use of the correction factor is not restricted to this. In fact, the use of the $K^{(i)}$ can be extended to any experiment designed to investigate the QGP formation or existing data and it can be applied to account for the higher order QCD corrections to the lowest order thermal dilepton production in a compact way. In all situations where an intial distribution of the quarks and anti-quarks in the thermal plasma can be assumed, the factor can be used to provide estimates of the thermal dilepton production, including the higher order corrections and thus can serve as an useful tool in determining QGP signatures.

ACKNOWLEDGMENTS

One of the authors (M.M.) would like to thank Prof. A. Goneid for helpful discussions and Ain Shams University for financial support. L. C. would like to thank the University Grants Commission of India for partial support. M. M., L. C. and Z.W. would like to thank Dr. M. Strayer, Dr. J. Ball and Dr. F. Plasil for their kind hospitality at ORNL. This research was supported in part by the Division of Nuclear Physics, U.S. Department of Energy under Contract No. DE-AC05-84OR21400 managed by Martin Marietta Energy Systems, Inc.

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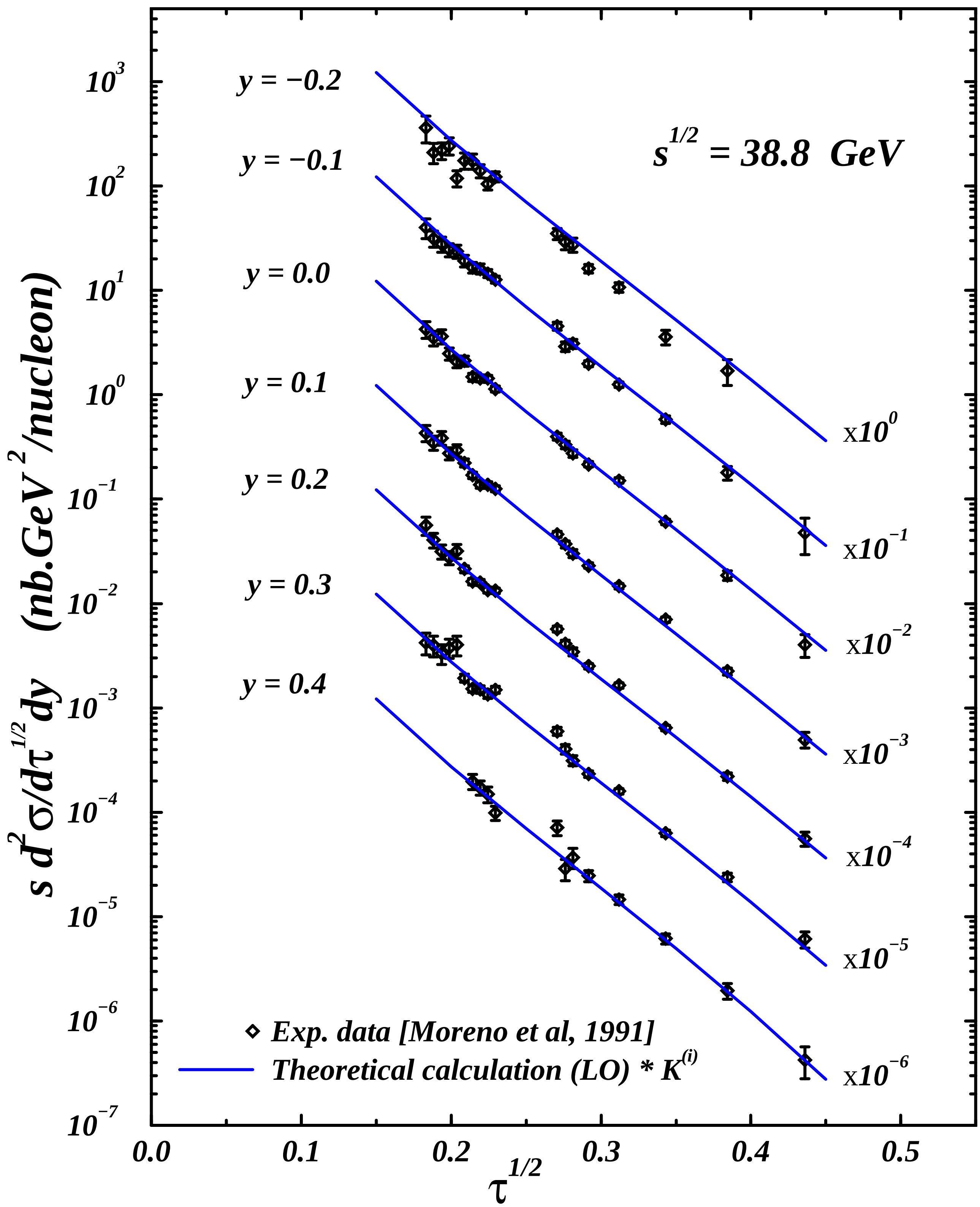
FIGURES

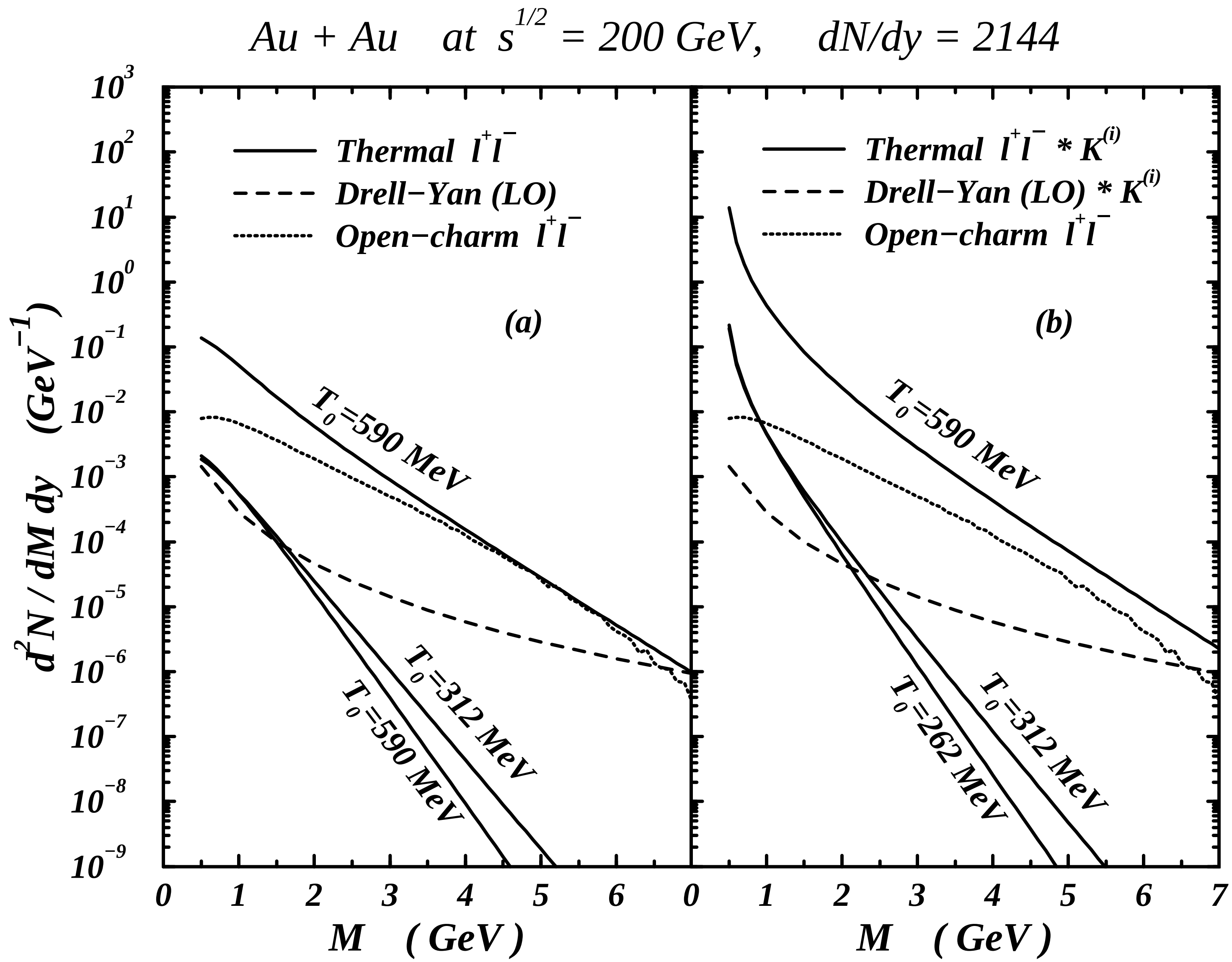
FIG. 1. The differential cross section $sd^2\sigma/d\sqrt{\tau}dy$ as a function of $\sqrt{\tau}$ for different rapidity y intervals. The data are taken from the FANL-605 experiment [21]. The solid curve are the fitting of the lowest order QCD calculations multiplied by the correction factor $K^{(i,f)}$, see text.

FIG. 2. Dilepton production rates from the collision Au+Au at RHIC energies ($\sqrt{s} = 200$ GeV) and $dN/dy = 2144$: (a) without the correction factor $K^{(i)}$ and (b) with the correction factor $K^{(i)}$.

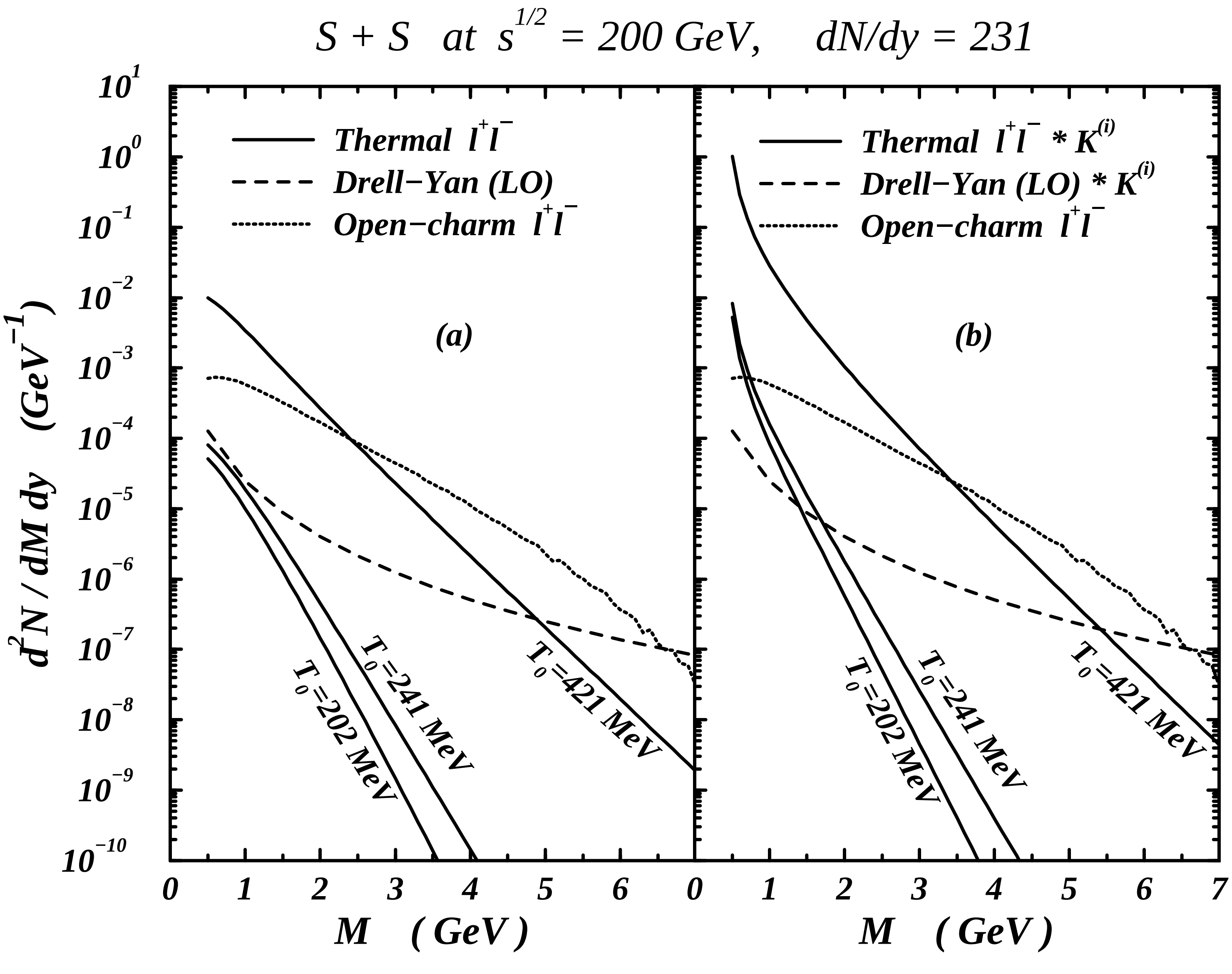
FIG. 3. Dilepton production rates in the collision S+S at RHIC energies ($\sqrt{s} = 200$ GeV) and $dN/dy = 231$: (a) without the correction factor $K^{(i)}$ and (b) with the correction factor $K^{(i)}$.



$s^{1/2}$ = 38.8 GeV
y = −0.2
y = −0.1
y = 0.0
y = 0.1
y = 0.2
y = 0.3
y = 0.4
x10^0
x10^{-1}
x10^{-2}
x10^{-3}
x10^{-4}
x10^{-5}
x10^{-6}
Exp. data [Moreno et al, 1991]
Theoretical calculation (LO) * $K^{(i)}$
$s\,d^2\sigma/d\tau^{1/2}dy$ (nb.GeV^2/nucleon)
$\tau^{1/2}$



Au + Au at s^1/2 = 200 GeV, dN/dy = 2144
d²N / dM dy (GeV⁻¹)
Thermal l⁺l⁻
Drell−Yan (LO)
Open−charm l⁺l⁻
(a)
T0=590 MeV
T0=312 MeV
T0=590 MeV
Thermal l⁺l⁻ * K(i)
Drell−Yan (LO) * K(i)
Open−charm l⁺l⁻
(b)
T0=590 MeV
T0=262 MeV
T0=312 MeV
M (GeV)
M (GeV)


S + S at s^1/2 = 200 GeV, dN/dy = 231
Thermal l+l−
Drell−Yan (LO)
Open−charm l+l−
(a)
T0=202 MeV
T0=241 MeV
T0=421 MeV
Thermal l+l− * K(i)
Drell−Yan (LO) * K(i)
Open−charm l+l−
(b)
d2N / dM dy (GeV−1)
M (GeV)